The impact of using geogrid capsules on the bearing capacity of strip foundations in sandy soils

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ABSTRACT

Soil is a material that exhibits good compressive strength but is weak under tension. To overcome tensile weakness and enhance shear strength, various soil improvement techniques are employed. Soil reinforcement is a common technique that uses natural or synthetic materials for this purpose. In recent years, materials like geosynthetics have seen significant development in soil reinforcement. Among the most common synthetic reinforcements are geogrids, which mobilize the friction at the interface between soil and reinforcement materials, thereby increasing both tensile and shear strength of the soil. This study examines the effect of geogrid capsules on the bearing capacity of strip foundations on sandy soils. The force-settlement variations were modeled and analyzed using the PLAXIS 2D finite element software to conduct sensitivity analysis for the research variables. In this study, after validating the numerical model, the impact of parameters such as capsule length, thickness, number of layers, distance from the foundation, and spacing between capsules on the ultimate bearing capacity of the strip foundation was investigated. The results of these analyses were presented in the form of dimensionless graphs, from which the optimal depth of placement, thickness, and number of encapsulated reinforcement layers were determined. The analysis results indicate that the use of geogrid capsules significantly improves the soil reinforcement outcomes compared to geogrid sheets. Additionally, increasing the number of capsule layers considerably enhances the bearing capacity of the strip foundation, with the highest bearing capacity observed at a depth ratio of 0.1. Ultimately, increasing the length and number of capsule layers results in higher bearing capacity and reduced settlement, due to the prevention of failure surface development beneath the capsule. Consequently, the optimal length and thickness of the capsule were determined.

KEYWORDS

Geogrid

Settlement

Reinforced Soil

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Bearing Capacity of Strip Foundation

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1. Introduction

In today's diverse construction site conditions, the method and performance of soil reinforcement are crucial. Soil inherently has good compressive and shear strength but is weak under tension. Various efforts have been made to overcome this tensile weakness, notably using geosynthetics in geotechnical engineering to improve soil bearing capacity. Researchers have conducted small- and large-scale experiments and numerical studies to evaluate the effectiveness of reinforced soil foundations and develop rational design methods. Notably, studies have focused on the impact of geogrid reinforcement on bearing capacity and settlement behavior. This study explores the optimal dimensions, layer count, and placement depth of geogrid capsules, highlighting their economic advantages over other geosynthetic reinforcements like geocells, while maintaining similar applicability.

2. Numerical modeling

The finite element software Plaxis 2D was used to simulate the effect of the geogrid capsule on the ultimate bearing capacity of the soil. For validation, the numerical models were compared with the results obtained from an innovative loading device in the Soil Mechanics Laboratory of Islamic Azad University, Hamedan Branch. The geogrid capsule was modeled by placing two layers of geogrid side by side, filled with strong sand. The model dimensions were determined to be 10 m high and 22 m wide, which included loose and strong sandy soils. A 2 m wide strip foundation was placed on the surface and centered on the loose sandy soil. In order to investigate the factors affecting the bearing capacity of strip foundations, 1 analysis in the unreinforced state and 30 analyses in the reinforced state were planned and carried out. The number of layers and length of the reinforcements, the distance of the reinforcements from each other and from the bottom of the foundation, and the thickness of the capsule were among the variables that were evaluated in order to investigate the effect on the bearing capacity of the strip foundation.

3. Experimental modeling

An innovative small-scale loading device was employed, using silica sand and Rockshield geogrid. Tests were conducted under dry conditions to analyze the effects of parameters. The test tank was filled to a height of 30 cm using the sand settling method to achieve the desired density. A geogrid capsule, filled with strong sand, was placed and buried. After testing, the soil for each test was drained and refilled. A metal strip footing was then secured to the surface without disturbing it. During load application, a hydraulic jack applied a constant displacement with a constant soil specific gravity and a loading rate of 1 mm/min. Settlement was the ultimate loading criterion, which continued up to 30% of the foundation width (15 mm) and the bearing capacity was considered at this final point.

Fig.1. The capsule used in the Experimental modeling

Table.1. Sand and Gravel Characteristics

Soil type	Parameter	Latin symbol	Unit	Value
Silica Sand (SP)	Modulus of elasticity of soil	E_s	KN/m^2	$15*10^3$
	Internal friction angle	ϕ	degrees (°)	34
	Choesion	C	KN/m^2	1
	Poisson's ratio	υ	-	0.3
	Soil specific gravity	γ	KN/m^3	19.5
Gravel (GP)	Modulus of elasticity of soil	E_s	KN/m^2	$5*10^4$
	Internal friction angle	ϕ	degrees (°)	38
	Choesion	C	KN/m^2	1
	Poisson's ratio	υ	-	0.35
	Soil specific gravity	γ	KN/m^3	20

4. Verification of results

The results of the numerical and experimental models were verified and found to be similar, with only minor differences, indicating that the results are correct.

5. Result and Discussion

The increase in bearing capacity due to soil reinforcement is expressed as a dimensionless parameter BCR (bearing capacity ratio) which is used to compare the bearing capacity in reinforced and unreinforced conditions with each other.

$$BCR_1 = \frac{qr_1}{q} \quad (1)$$

$$BCR_2 = \frac{qr_2}{q} \quad (2)$$

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In the following, in order to analyze the sensitivity of the effect of parameters such as the distance of the reinforcement from the level below the foundation floor, length, number of layers of reinforcement, thickness of the capsule layer, bearing capacity ratio (BCR) and bearing capacity in different cases are plotted and compared. For this reason, the parameter whose amount and manner of effect is to be determined in the analyses is considered as a variable parameter and the other parameters are considered fixed An evaluation of the effect of reinforcement length on the bearing capacity of a strip foundation, where both length and height were varied at a constant distance from the footing, showed a 26% increase compared to the unreinforced condition. Similarly, increasing the capsule height to 0.3B resulted in a 26% improvement in bearing capacity. The optimal placement, with three capsule layers near the footing, resulted in a 68% increase in bearing capacity compared to the unreinforced condition.

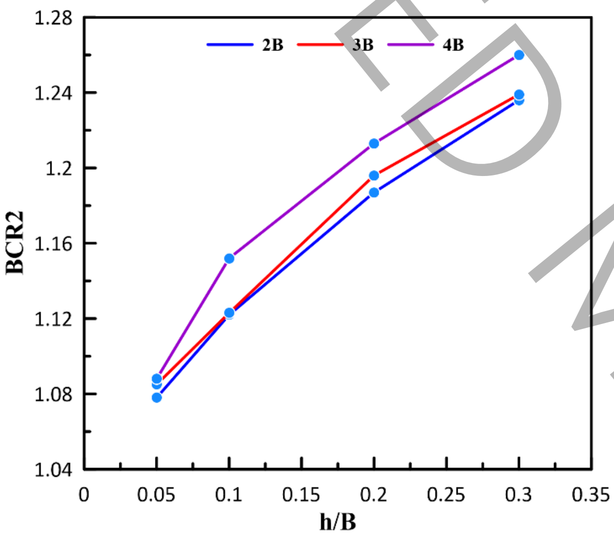

Fig. 2. Diagram of changes in BCR_2 focusing on the effect of capsule height with h=0.05B, h=0.1B, h=0.2B, h=0.3B.

6. Conclusions

Results from 2D PLAXIS finite element modeling of a strip footing on sandy soil using geogrid encapsulation indicate a significant improvement in bearing capacity due to the structure of the capsules. Key findings include:

1. Optimal benefits are achieved when the top of the capsule is 0.1B below the foundation. Greater depths can lead to lateral spreading of the soil and reduced performance.

2. Increasing the capsule width to 4B effectively prevents the development of the failure surface and increases load distribution.

3. Capsule height increases stiffness, with optimal performance at a height of 0.3B, preventing local buckling.

4. Adding more capsule layers improves performance by preventing the development of the failure surface, with best results at 1 to 3 layers at a distance of 0.1B and a height of 0.3B.

5. Bearing capacity increases continuously with geogrid reinforcement, with the greatest improvement seen in three-layer configurations.

7. References

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